

[54] **ROTARY SOLENOID SHUTTER DRIVE ASSEMBLY AND ROTARY INERTIA DAMPER AND STOP PLATE ASSEMBLY**

[76] Inventors: **James C. Fletcher**, Administrator of the National Aeronautics and Space Administration with respect to an invention of; **Walter L. Cable**, Freehold, N.J.; **Harold B. Dougherty**, Hightstown, N.J.

[22] Filed: **May 21, 1973**

[21] Appl. No.: **361,906**

[52] U.S. Cl. **354/234, 95/53 EA, 350/269**

[51] Int. Cl. **G03b 9/16, G03b 9/42**

[58] Field of Search..... **95/53 E, 53 EA, 55; 350/269, 272; 335/219, 272**

[56] **References Cited**
UNITED STATES PATENTS

2,909,978 10/1959 Fischer et al. 95/55 X

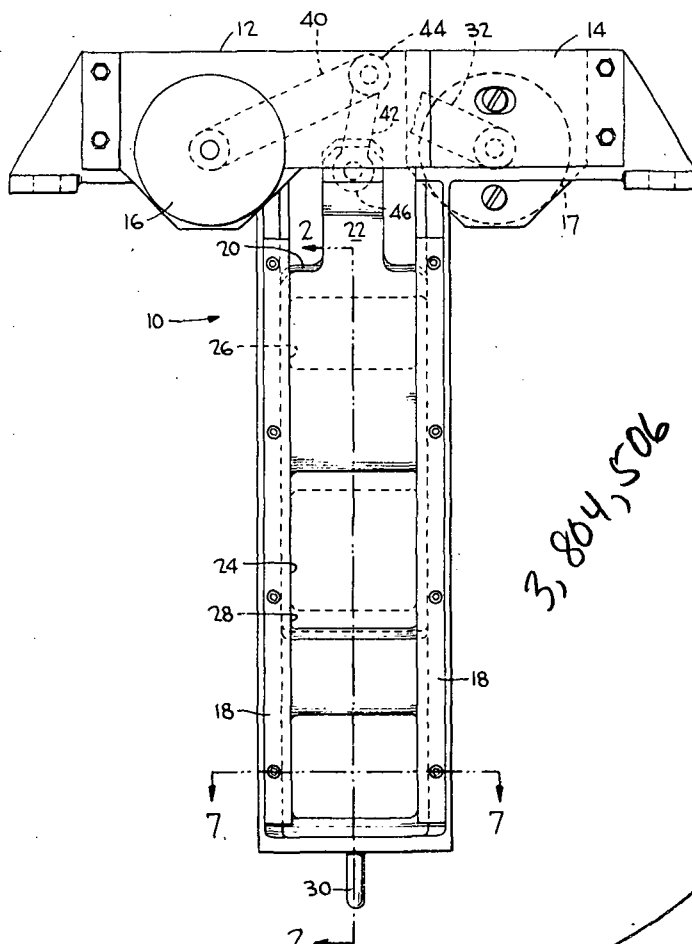
3,726,199	4/1973	Alfredsson et al.	95/53 EA
3,724,350	4/1973	Mielke	95/53 E
3,176,170	3/1965	Fulton et al.	95/55 X
3,381,597	5/1968	Morton	95/55
3,009,406	11/1961	Takahama	95/55 X
3,435,394	3/1969	Eggen	335/272
3,664,251	5/1972	Vincent	95/53 E

Primary Examiner—Joseph F. Peters, Jr.
Attorney, Agent, or Firm—R. F. Kempf; J. R. Manning; J. H. Warden

[57] **ABSTRACT**

A camera shutter assembly having a pair of superposed opaque planar shutter blades, each having an aperture and being arranged for reciprocal linear movement is disclosed. A pair of rotary solenoids, each connected to one of the blades by a linkage and arranged to be actuated separately at a predetermined interval is provided. An inertia damper and stop plate is built into each solenoid to prevent rebound.

6 Claims, 12 Drawing Figures



3,804,506

(NASA-Case-GSC-11560-1) ROTARY SOLENOID SHUTTER DRIVE ASSEMBLY AND ROTARY INERTIA DAMPER AND STOP PLATE ASSEMBLY Patent (NASA) 8 p CSCS 09E

00/09

Unclas 36173

N74-20861

FIG. 1

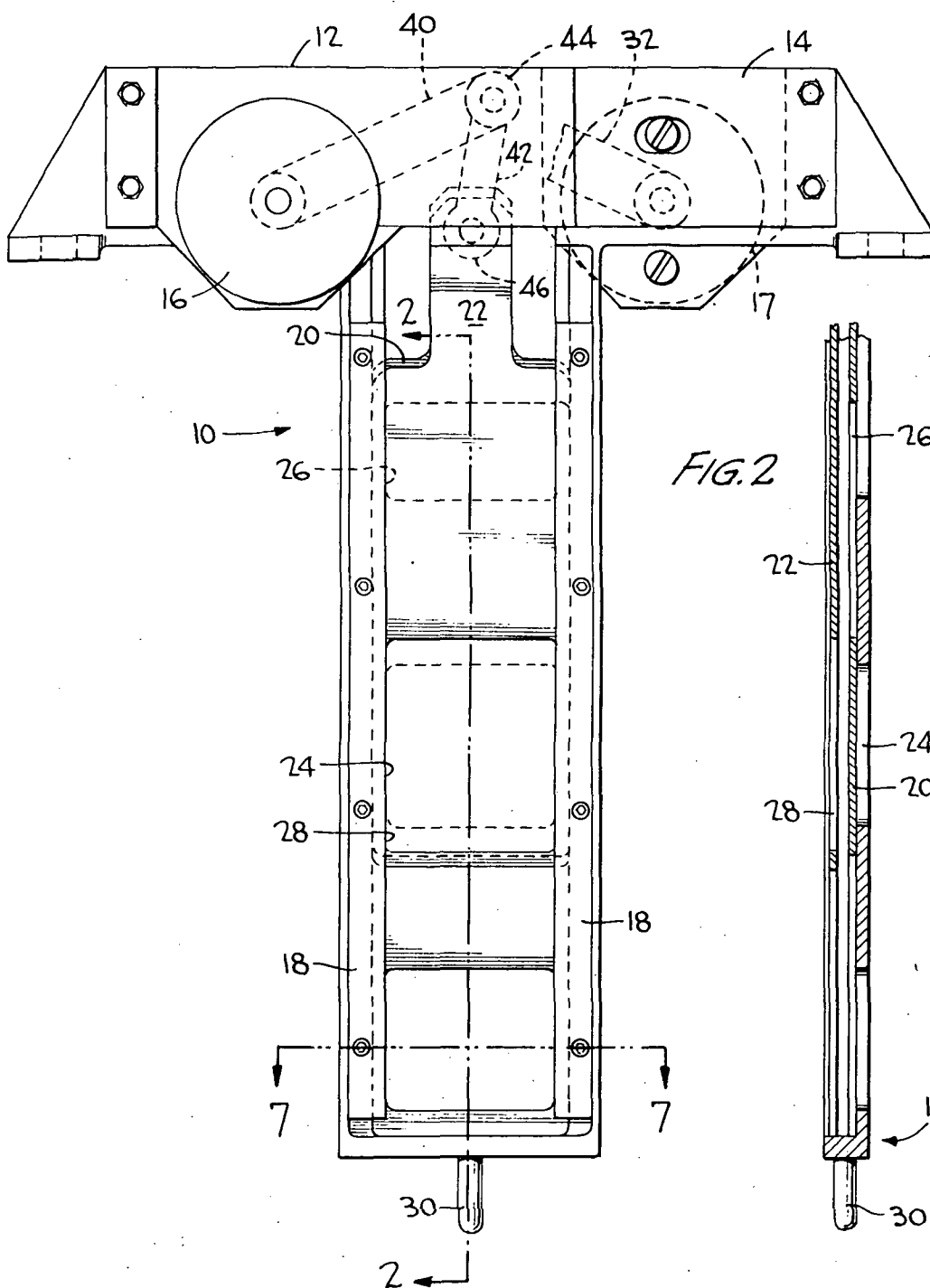


FIG. 2

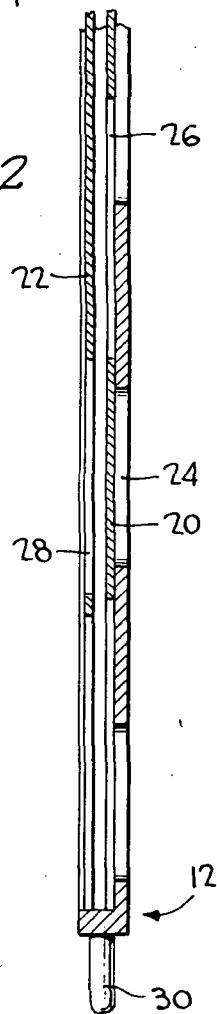


FIG. 3

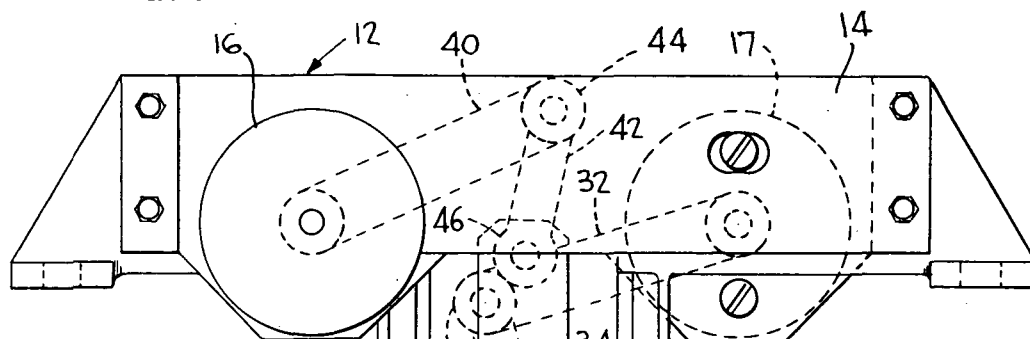


FIG. 4

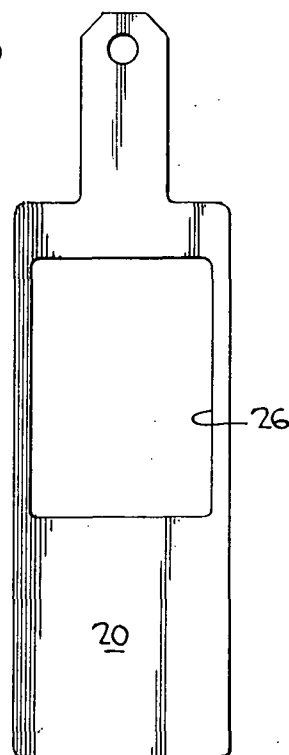
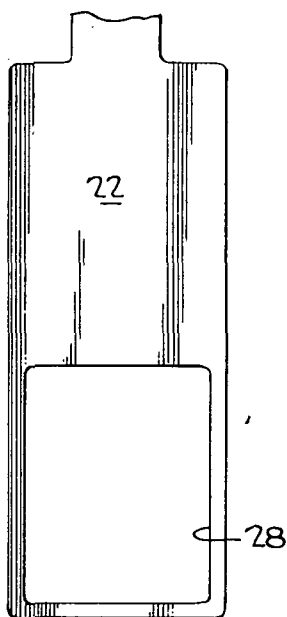


FIG. 5



18

20

30

10

22

26

28

24

18

26

20

28

FIG. 6

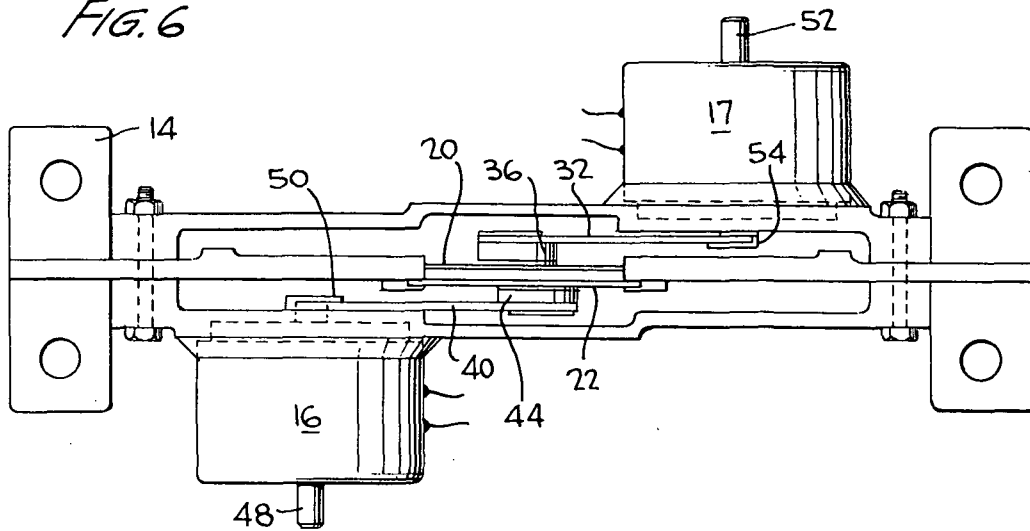


FIG. 7

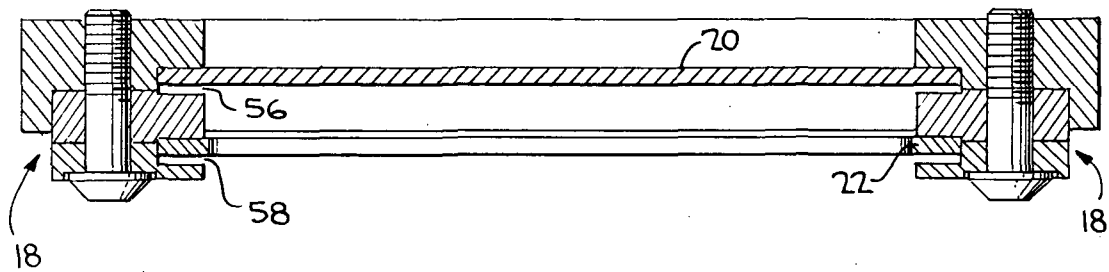
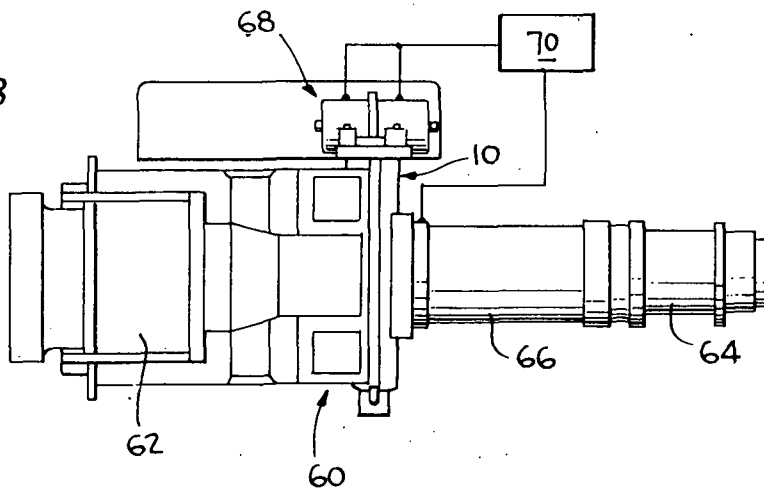
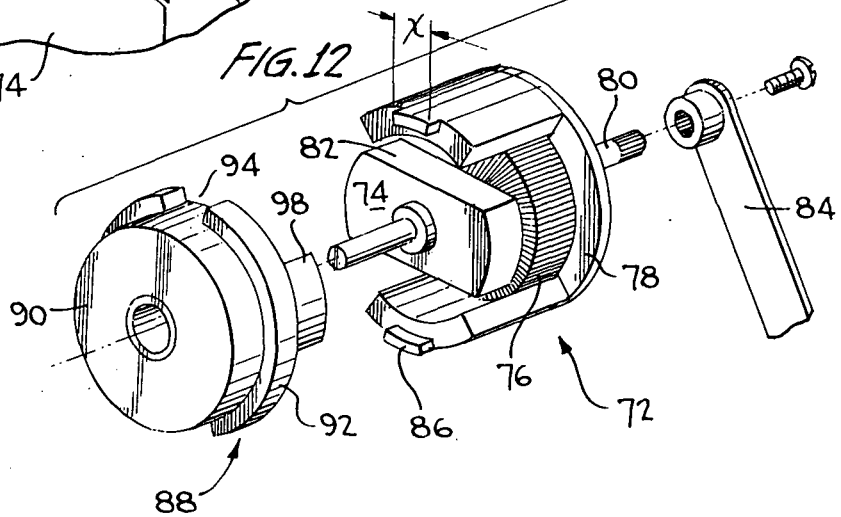
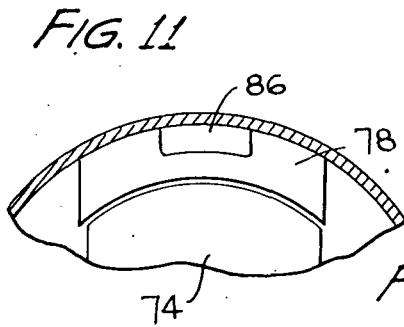
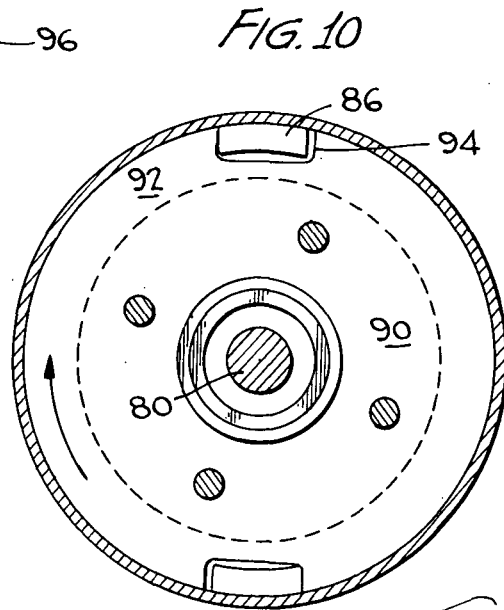
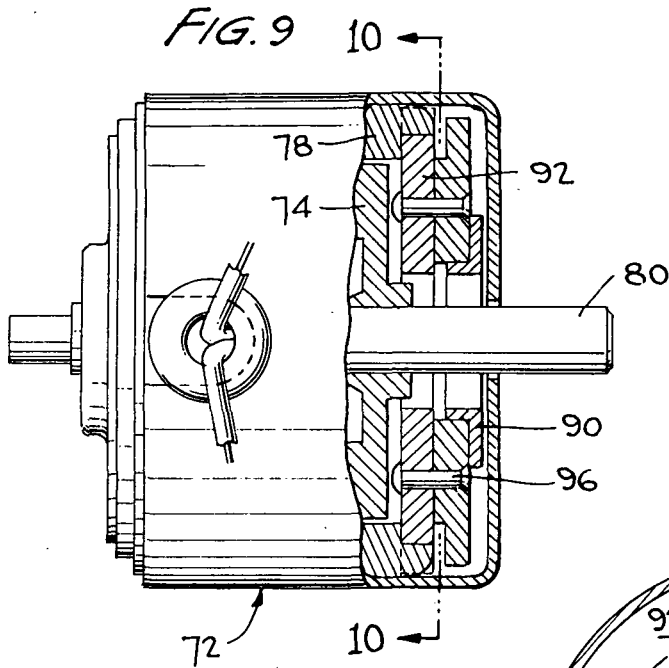


FIG. 8





ROTARY SOLENOID SHUTTER DRIVE ASSEMBLY AND ROTARY INERTIA DAMPER AND STOP PLATE ASSEMBLY

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

This invention generally relates to cameras, and more particularly, this invention relates to a camera shutter having long life and extreme accuracy.

Various types of cameras and camera shutters have been developed over many years, each type being suitable for a particular need and environment. While a generalization can be made that all cameras, for practical purposes, include a lens or other optical system for focusing an image, a shutter for controlling the exposure, and some means for recording the image, such means being either a light-sensitive photographic film or electronic apparatus, it is also clear that these elements vary widely according to the ultimate purpose for which the camera will be used.

It is apparent that for use in a satellite a camera must be able to operate under a wide variety of conditions and must be able to withstand extremes of temperature and mechanical abuse. For example, at the time of launching the satellite the camera will be subjected to forces many times that of gravity and, once the satellite is in orbit, the camera will be operating essentially in a vacuum and at wide temperature extremes. Thus, it will be appreciated that such a camera must be designed to withstand these various types of abuse and to be extremely reliable due to the impossibility to effect repairs and adjustments. In such a camera various conventional electronic means for recording an image and, eventually, transmitting the same to earth are available. Similarly, lens systems which are capable of withstanding the extremes of shock and temperature are also available. The most delicate and, therefore, difficult to construct, is the shutter system. Such a shutter system must be capable of providing an extremely small exposure time (from about 4 to about 16 milliseconds) at small tolerances (± 0.4 milliseconds) and have an extremely long endurance life.

SUMMARY OF THE INVENTION

It is, therefore, a primary object of the present invention to provide a camera shutter for extremely short exposure times and having a long endurance life.

It is another primary object of the present invention to provide a camera shutter having extreme accuracy and a low level of shock at the end of a blade stroke.

It is another object of the present invention to provide a simply constructed camera shutter having a double blade system combined with rotary solenoids having an inertia damper assembly.

It is still another object of the present invention, consistent with the foregoing objects, to provide a camera capable of withstanding extremes of shock and temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects will become apparent as the description of the invention proceeds, such description making reference to the annexed drawings wherein:

FIG. 1 is a front elevational view of the shutter assembly of the instant invention with the shutter blades in the "cocked" position;

FIG. 2 is a sectional view taken on the line 2—2 of FIG. 1;

FIG. 3 is a vertical elevational view of the apparatus of FIG. 1 illustrating the start of a shutter opening operation;

FIG. 4 is a plan view of the direct blade of the apparatus of FIG. 1;

FIG. 5 is a plan view of the indirect blade of the apparatus of FIG. 1;

FIG. 6 is a plan view of the apparatus of FIG. 1;

FIG. 7 is a sectional view taken on the line 7—7 of FIG. 1;

FIG. 8 is a schematic elevational view of the camera assembly according to the instant invention;

FIG. 9 is a partially sectional elevational view of the solenoid used in the shutter of the instant invention;

FIG. 10 is a sectional view taken on the line 10—10 of FIG. 9;

FIG. 11 is a partially fragmented, partially sectional view of the solenoid of FIG. 9 and;

FIG. 12 is an exploded view of the solenoid used in the shutter of the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2 for a basic understanding of the instant invention, there will be seen a camera shutter generally designated by the numeral 10, such shutter generally having a T-shaped frame 12 which includes a pair of rails 14 each bearing a solenoid assembly 16, 17. A set of gibs 18 are provided to guide the two shutter blades. The shutter blades consist of a direct blade 20 and an indirect blade 22. Frame 12 also includes, between the gibs 18, an aperture 24. Direct blade 20 has an aperture 26 and direct blade 22 has an aperture 28. A foot 30 is provided for aligning the shutter assembly in the camera. Direct shutter blade 20 is driven by solenoid 17 by linkage means generally comprising arm 32 and link 34 (FIG. 3) connected at the pivot points by bushings 36 and 38 made of any suitable material such as Delrin. Similarly, indirect blade 22 is driven by solenoid 16 through arm 40 and link 42 with bushings 44 and 46 provided at the pivot points.

Turning momentarily to FIGS. 4 and 5, it will be seen that direct blade 20 has an aperture 26 in the upper portion thereof while indirect blade 22 has aperture 28 in the lower portion thereof. Returning to FIGS. 1 and 2, it will be seen that both direct blade 20 and indirect blade 22 are in the deenergized, or cocked position. In this position, aperture 24 is blocked. As will be described in more detail hereinbelow, to make an exposure, the direct solenoid 17 is actuated thereby moving the direct blade 20 downwardly and aligning aperture 26 with aperture 24. After a pre-determined interval, indirect solenoid 16 is actuated thereby moving indirect blade 22 downwardly and beginning to close the aperture. FIG. 3 shows the relationship of the blades 20 and 22 part-way through the exposure when direct blade 20 has moved downwardly to expose part of ap-

erture 24 and indirect blade 22 has not yet begun its travel.

Certain aspects of the operation of shutter assembly 10 will be clarified by referring to FIGS. 6 and 7 wherein it will be seen that solenoids 16 and 17 are mounted on opposite sides of frame 12. Arm 40 is solidly fastened to output shaft 48 at 50 by any suitable means known in the art. Similarly, arm 32 is solidly fastened to output shaft 52 of solenoid 17 at 54 by suitable means. Direct blade 20 and indirect blade 22 are guided in their linear movement by channels 56 and 58, respectively in gibs 18.

Attention is now drawn to FIG. 8 which depicts shutter assembly 10 in place in a camera generally designated by the numeral 60. Camera 60 includes lens assembly 62, shutter assembly 10, and vidicon assembly 64. Vidicon assembly 64, the construction and operation of which are conventional and well known in the art, includes yoke 66.

The electrical connections of solenoids 16 and 17 are shown schematically at 68. The solenoids 16 and 17 are operatively connected, along with vidicon assembly 64, to control means 70 which is made in a conventional manner and serves the purpose of actuating the solenoids 16 and 17 to produce an exposure while controlling the vidicon assembly to record the image which is produced at the focal plane of lens assembly 62. The image thus recorded by vidicon assembly 64 can be transmitted to a remote location by conventional electronic means. It should be noted that when shutter assembly 10 is mounted in camera 60, pin 30 is seated in a suitable bushing such as one fabricated of polyurethane in order to minimize microphonic effects on the vidicon assembly 64.

In operation, control means 70 actuates direct solenoid 17 which then moves direct blade 20 through arm 32 and link 34. When direct solenoid 17 is actuated, direct blade 20 begins its movement downwardly thereby beginning to open aperture 26 to produce the exposure. After a pre-determined interval, for example, 4, 8, or 16 milliseconds, after power is applied to direct solenoid 17, indirect solenoid 16 is actuated thereby moving indirect blade 22 by means of arm 40 and link 42. This movement of indirect blade 22 begins to close the aperture. The blade speed and power timing are such that the two blades 20 and 22 move across the aperture 26 in a manner to create a moving slit across the same. The choice of the differential in power timing, such as 4, 8, or 16 milliseconds, will result in differing widths of the moving slit, with a higher time differential creating the wider slit. Thus, the exposure is determined by the size of the slit.

It will be obvious to one of ordinary skill in the art that the possibility exists in a shutter of the type described above that at the end of the stroke of the blades there will be a bounce or rebound of one or both of the blades thereby producing vibration and/or double exposure. Accordingly, in another aspect of the present invention, means are provided for eliminating such a possibility, such means taking the form of a particular modification of the rotary solenoids to accomplish this result. In this regard, attention is directed to FIGS. 9 through 12 wherein the construction of the rotary solenoids is shown. It should be apparent that this construction is identical for both solenoids 16 and 17. Thus, for purposes of this discussion, the solenoid is generally designated by the numeral 72. The rotary solenoid as-

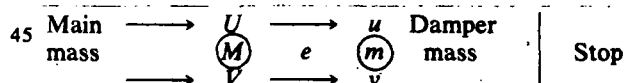
sembly 72 basically consists of an armature 74, core 76, stator 78, and output shaft 80. Output shaft 80 is fixed to armature 74 which is constructed so as to have a pair of opposed "chordal lands" or flats 82. Drive arm 84 is secured to output shaft 80 and, in turn, is operatively connected to one of the blades 20 or 22 by means of a link. Stator 78 has a pair of tabs 86 projecting outwardly, each of the tabs 86 having a width "x."

A damper assembly 88 is provided, the damper assembly including a heavy metal ring 90 and a stop plate 92 made of Delrin which is a polyoxymethylene thermoplastic polymer made by the polymerization of formaldehyde and being hard, rigid, strong, tough and resilient as well as being dimensionally stable. Of course, the stop plate can be fabricated of any material having the properties of Delrin. The stop plate 92 has a pair of opposed slots 94 corresponding to tabs 86 which will fit thereinto and having a width of 0.020 inch greater than "x." The stop plate 92 is secured to the heavy metal ring 90 by any suitable means such as rivets 96.

Particular characteristics of the damper assembly 88 are that the inertia of the assembly is matched with that of the rest of the armature-linkage-blade system in approximate ratio of 1 to 2 and it permits the damper assembly 88 to rotate beyond the point of initial impact by approximately 0.020 inch peripherally. It will be recognized that the impact referred to is that of the armature 74 against armature stroke limiting stop 98 of stop plate 92.

The combination of the sized inertia and the amount of over travel present a controlled multiple collision reaction of the armature-blade system against the stop plate which reduces the coefficient of restitution in the system and consequently significantly reduces the bounce at the end of the stroke and, therefore, eliminates double exposure.

The mechanism of the multiple collision stop plate can be illustrated by the simple analog of two colliding elastic balls and a fixed stop plate. Consider two balls of mass M and m travelling at speeds U and u respectively along their line of centers with $U > u$.



After collision the velocities of the two balls are V and v where, from the conservation of momentum

$$MU + mu = MV + mv$$

and for a coefficient of restitution e

$$v - V = -e(u - U) \text{ so that}$$

$$V = MU + mu - em(U - u) / M + m$$

$$v = MU + mu + eM(U - u) / M + m$$

For example if the second (damper) mass is half the primary mass, and is initially at rest then for a coefficient of restitution of $\frac{1}{2}$ we have

$$m = M/2, u = 0, e = \frac{1}{2}$$

so that $V_1 = U/2$

and $v_1 = U$

The damper mass then moves ahead and hits the end stop and is reflected with speed $-e \times$ incident i.e. $-U/2$. A second collision between the masses occurs with ini-

5

tial speeds of $U/2$ and $-U/2$ resulting in post-collision speeds of

$$V_2 = 0$$

$$v_2 = U/2$$

The damper mass then strikes the stop plate for the second time and is reflected with speed $-U/4$. Finally the damper mass hits the main mass for the third collision resulting in speeds

$$V_3 = -U/8$$

$$v_3 = 0$$

so that the damper mass comes to rest and the main mass is reflected after these multiple collisions with $1/8$ of its incoming speed. A single collision with a fixed stop plate would give return speed of $1/2$ the incident speed so that the multiple collision bumper is four times as effective in reducing the return speed.

The measured inertia of the Delrin and heavy metal stop plate was approximately half that of the rest of the system and a coefficient of restitution of 0.5 for Delrin-to-steel collisions is typical. In the simple example provided, the collisions have been assumed to be instantaneous. In real life the finite time taken by the collisions must of course be taken into account and they do lead to less reduction in velocity, however the simple example cited is illustrative of the method of energy dissipation.

Actuation of each rotary solenoid produces a 65° rotation of the shaft as limited by the internal stop plate. The 65° rotation, via the arm and link, produces a linear motion of the specific blade associated with that solenoid. Thus, using the device of the instant invention a uniformity of exposure across the aperture and a repeatability of exposure have been achieved both of which are within ± 0.4 millisecond over a temperature range of 0°C to 50°C . This performance is achievable for a life of 1 million cycles in a vacuum of 10^{-5} torr. The shutter assembly will maintain this accuracy for any exposure time from 4 to 16 milliseconds with simple adjustment of the input electrical pulses to the direct and indirect solenoids. This shutter assembly also can be used as a means for rapid insertion and retraction of lens filters on cameras and can be applied in such a way as to provide a relatively high number of filters within a reasonably small package. The filters would merely replace the shutter blades and would be driven and held on command through rotary solenoids designed for continuous duty. Furthermore, the device can be used to produce a variety of shutter exposure times over a wider range by adjustment of solenoid torque, solenoid pulse timing, linkage ratios, blade to aperture sizing and degrees of solenoid stroke.

It should be apparent from the foregoing detailed description that the objects set forth hereinabove have

6

been successfully achieved. Moreover, while there is shown and described a present preferred embodiment of the invention, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practised within the scope of the following claims. Accordingly,

What is claimed is:

1. A camera shutter assembly comprising a pair of superposed opaque planar shutter blade members, each said member having aperture means therein and being arranged for reciprocal linear movement between an initial rest position and a final rest position; a pair of rotary solenoids, each of said solenoids being operatively connected to one of said blade members by linkage means to cause movement of said blade members when said solenoids are actuated; and means for actuating said solenoids such that one of said solenoids is actuated at a predetermined time interval before the other of said solenoids, whereby predetermined portions of said aperture means coincide for a predetermined period of time to permit the passage of incident radiation.

2. A shutter assembly defined in claim 1, wherein said predetermined time interval ranges from about 4 to 16 milliseconds.

3. A shutter assembly as defined in claim 1, wherein each of said solenoids comprises a core, stator means having a pair of opposed arms and at least partially surrounding said core, armature means having a pair of opposed chordal lands, and substantially fixed damper means, said damper means comprising a heavy metal ring and a stop plate, said stop plate having a pair of opposed armature limiting stops, one of said linkage means being fixed to said armature means through an outlet shaft, said damper means having an inertia equal to one-half the inertia of said armature means, said one of said linkage means, and a corresponding blade member.

4. A shutter assembly as defined in claim 3, wherein said stop plate is fabricated of a material having the characteristics of a polyoxymethylene thermoplastic polymer made by the polymerization of formaldehyde.

5. A shutter assembly as defined in claim 3, wherein each of said arms of said stator means has a tab extending therefrom and said stop plate includes a pair of slots which mate with said tabs, said slots being 0.020 inch wider than said tabs, whereby when said armature means engages said stop plate, said stop plate will travel at most 0.020 inch from the impact.

6. A camera assembly comprising the shutter assembly of claim 1, a lens assembly and a vidicon assembly, said shutter assembly being interposed between said lens assembly and said vidicon assembly.

* * * * *

60

65

